

Method for Controlling an Automatic Transmission

Background of the Invention

The present invention relates to a method for controlling the automatic transmission in a motor vehicle having an engine, wheels, a wheel slip control system and an automatic transmission having a clutch.

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In a vehicle having automatic transmission, certain roadway conditions can lead to less than optimal performance of the automatic transmission during gear shifting. For one example, icy, wet, or otherwise slippery road surfaces may result in wheel slippage immediately following a gear change. When shifting up on a slippery surface, there is a danger of wheel slippage in the positive direction (drive slip). Also, when downshifting on a slippery road surface, there is a danger of wheel slippage in the negative direction (brake slip).

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Another example of less than optimal performance of the automatic transmission during gear shifting occurs when starting the vehicle from rest in conditions where there is a high resistance to travel, e.g. a steep roadway inclination,

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deep snow, etc. When the vehicle begins to move from rest, the automatic transmission is in the start mode, and thus it allows the clutch to slip until a certain minimum vehicle speed is obtained. In situations where there is a high resistance to vehicle travel, such as when the vehicle is on an upward incline or in deep snow, the vehicle usually takes longer to reach the minimum vehicle speed leading to a heat load and faster wear of the clutch. In some circumstances it can lead to permanent damage to the clutch.

#### Summary of the Invention

In vehicles having a wheel slip control system, understood here to be a system capable of determining the friction coefficients between the wheel and the roadway surface, the slippage of the wheel, the wheel speed and the vehicle speed. Signals that are generated based upon these values can be used to improve transmission control to help eliminate the aforementioned problems. Examples of wheel slip control systems include antilock braking systems ("ABS"), traction control systems ("TCS" or "ASR"), automatic brake force differential lock systems ("ABS/ADS"), or electronic stability program ("FDR or ESP").

The present invention relates to a method of controlling a drive train of a motor vehicle having an engine, a wheel slip control system, and an automatic transmission having a clutch,

characterized in that the automatic transmission is controlled based upon signals generated by the wheel slip control system.

In an exemplary embodiment of the present invention, the automatic transmission can be controlled to reduce wheel slippage on slippery road surfaces based upon signals indicating that a coefficient of friction between a wheel and a roadway surface are less than a predetermined friction coefficient value. A signal indicating the current engine speed may also be used. The automatic transmission can be controlled by controlling the closing of the clutch including controlling both when, and how quickly, the clutch is closed. For example, the clutch can be closed more slowly if the engine speed is not at or near a target engine speed for the gear being shifted into. The closer the engine speed is to the target engine speed, the more quickly the clutch can be closed without danger of wheel slippage. In another exemplary embodiment, the automatic transmission is controlled by adjusting the engine speed in addition to controlling the closing of the clutch. The engine speed can be adjusted, for example by controlling the throttle valve angle, to more closely approximate a target engine speed value.

In another exemplary embodiment, when trying to start a vehicle from rest in high resistance conditions, the automatic transmission is controlled when the vehicle speed is less than

a predetermined vehicle speed and an elapsed time since vehicle start is greater than a predetermined time value. In place of comparing time, the number of slip cycles of the clutch may be compared with a corresponding predetermined value. When the wheel slip control system indicates that the vehicle speed is less than a predetermined vehicle speed value and the time since vehicle start is less than a predetermined time, the automatic control system can be controlled by increasing the engine speed and closing the clutch, thus alleviating unneeded strain on the clutch.

#### Brief Description of the Drawings

Figure 1 is a block diagram illustrating components of an exemplary embodiment and their functions.

Figure 2 is a flow chart illustrating a routine performed by the transmission control in an exemplary embodiment adapted for slippery road surface conditions.

Figure 3 is a flow chart illustrating a routine performed by the transmission control in another exemplary embodiment adapted for conditions with high resistance to vehicle start up.

#### Detailed Description

The invention is illustrated below with reference to several

exemplary embodiments.

In Figure 1, the relationship between the functional components of the motor vehicle are illustrated. Although an engine control 10a, a transmission control 12a, and a wheel slip control 15 are shown here as three different units for the sake of clarity, it is not intended to illustrate that the functions of transmission control 12a, engine control 10a, and wheel slip control 15 must reside in three separated hardware units.

Obviously, these functions may be performed by one or more control units. The basic components and functions illustrated in Figure 1 are known.

A velocity  $v_R$  of wheel 13 is monitored by the wheel slip control system 15, and that value is passed along to the transmission control 12a. A vehicle velocity  $v_V$  may be calculated based in part on the velocity of one or more wheels  $v_R$  or by other known methods and passed on to the transmission control 12a. The wheel slip control system unit 15 also determines the coefficient of friction  $\mu$  between the wheel 13 and the roadway surface (not shown) and passes that value to the transmission control unit 12a. The transmission control unit 12a also receives information about the current engine speed  $N_{Mot}$  from the engine control 10a (or if combined with the engine control, directly from a sensor on the engine 10). The transmission control 12a can send a signal TVA to the engine

control 10a causing the throttle valve angle to be adjusted, and by so doing, affecting the engine speed  $N_{\text{Mot}}$ . The transmission control 12a also receives a signal indicating the current transmission speed  $M_{\text{Tr}}$  and the current gear  $i$  from the transmission 12 and sends a signal to change the gear to the desired gear  $i_{\text{sol1}}$  to the transmission 12. the clutch 11 sends a signal to the transmission control indicating its present status (whether or not, or to what degree it is closed  $S_{\text{yes/no}}$ ) and receives a signal to open or to close  $K_{\text{open/close}}$  (and, in some cases also how quickly to open or close). The transmission control 12a also contains a processor to process the signals and to control the transmission based on the inputs it receives. The routines used to process those signals and to control the transmission are illustrated in more detail in Figures 2 and 3.

Figure 2 is a flow chart illustrating an exemplary routine performed by the transmission control 12a during a gear shift mode based on inputs described in Figure 1. The routine is used to improve the control of the transmission to reduce slippage on slippery road surfaces during gear shifting.

In the first step, the routine begins when the automatic transmission begins a gear changing procedure. In steps 202 and 203 the clutch 11 opens and a gear  $i$  is changed to the desired gear  $i_{\text{sol1}}$ . Next, in step 204 the current coefficient of

friction  $\mu$  between the wheel and the roadway surface is compared to a predetermined coefficient of friction value  $\mu_0$ .

If the coefficient of friction  $\mu$  is not below the predetermined value  $\mu_0$ , the clutch is closed and the routine ends. If

5 however, the coefficient of friction  $\mu$  is below the predetermined value  $\mu_0$  (indicating a slippery roadway surface), the current engine speed  $N_{Mot}$  is then compared to a target engine speed  $N_z$  in step 205.

10 The target engine speed is calculated based on the current wheel speed  $v_R$  and the gear  $i$ , so that the target engine speed  $N_z$ , when translated by the transmission, results in a value approximately equal to the driven wheel speed. The following equation can be used:

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$$N_z = \eta * i_{soll} * (VANL + VANR/2) * c$$

where  $\eta$  = efficiency, which here is approximately 0.8

$VANL$  = left driven wheel speed

$VANR$  = right driven wheel speed, and

20  $c$  = a constant, which here is approximately 0.12

If the current engine speed  $N_{Mot}$  is approximately equal to the target engine speed  $N_z$  the clutch is closed and the routine ended. However, if the current engine speed  $N_{Mot}$  is greater or  
25 less than the target engine speed  $N_z$  by a significant amount, for example 100 rpms, the engine speed  $N_{Mot}$  is adjusted in step

205 to more closely approximate the target engine speed  $N_z$   
(i.e.  $N_{Mot}$  is increased if less than  $N_z$  and decreased if greater  
than  $N_z$ ).

5 Steps 205 and 206 are then repeated until the target engine  
speed  $N_z$  is approximately reached, at which time the clutch 11  
is closed and the routine ended. Because the clutch 11 is only  
closed once the target engine speed  $N_z$  has been reached, a  
smoother gear shifting results. Also, there will be little if  
10 any slippage of the wheels, because, at the time that the  
clutch closes, the engine speed translated by the transmission  
approximates the wheel speed.

In an exemplary embodiment, the speed at which the clutch  
15 closes may relate to the allowable range for the engine speed  
 $N_{Mot}$  (in comparison to the target engine speed  $N_z$ ). Thus, if the  
engine speed  $N_{Mot}$  has not yet reached the target engine speed  
 $N_z$ , but has reached an acceptably close value, the clutch may  
close, but do so more slowly. However, if the engine speed  $N_{Mot}$   
20 has reached a value much closer to the target engine speed  $N_z$ ,  
the clutch may close more quickly without the risk of wheel  
slippage. The partial engagement of the clutch during a slow  
closing procedure will in itself work to adjust the engine  
speed to more closely approximate the target engine speed  $N_z$ .

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Figure 3 is a flow chart illustrating an exemplary routine



performed by the transmission control 12a for an improved transmission control for vehicle starts from rest in situations in which the resistance to vehicle start is high. The routine results in a more efficient start in such situations and helps  
5 reduce heat build-up and damage to the clutch 11, in such situations.

The routine in Figure 3 begins with step 301 when the vehicle is stopped and the selected gear is park or neutral. In step  
10 302, the driver chooses a drive gear and begins to drive off. Next, in step 303 a current vehicle speed  $v_v$  is compared to a predetermined vehicle speed value  $v_{v0}$ . The current vehicle speed  $v_v$  can be determined by measuring a single wheel speed  $v_R$ , by averaging the speed of several wheels, or by other known  
15 methods. The predetermined vehicle speed value  $v_{v0}$  represents the minimum vehicle speed for which the present gear can be fully engaged without putting too much resistance on the engine causing the vehicle to jerk or stall. If the vehicle has exceeded the predetermined vehicle speed  $v_{v0}$ , the clutch is  
20 engaged and the routine ended. If the vehicle speed  $v_v$  has not reached the predetermined vehicle speed  $v_{v0}$ , an elapsed time since vehicle start from rest (or, an elapsed time since the start of wheel spinning)  $T_e$  is compared with a predetermined time value  $T_0$  in step 304. The predetermined time value  $T_0$   
25 represents the time that is normally expected for the vehicle to reach the predetermined vehicle speed  $v_{v0}$ . If the elapsed

time  $T_e$  has not yet exceeded the predetermined time value  $T_0$ , steps 303 and 304 are repeated. Once the predetermined time value  $T_0$  is exceeded, the engine speed is increased in step 305 and the clutch is closed in step 306. By increasing the engine speed  $N_{Mot}$  and closing the clutch, the heat build up and excessive wear of the clutch is avoided in situations where the resistance to vehicle travel is high.

In another exemplary embodiment, step 304 could be replaced by comparing the number of clutch slip cycles instead of measuring time. Thus, if the clutch slipped more than a predetermined number of cycles, the transmission control 12a would increase the engine speed and cause the clutch 11 to close. The step 305 could also be expanded, for example, to include the step of calculating a predetermined engine speed appropriate for the situation (given the roadway friction coefficient, the roadway inclinations, vehicle mass, etc.) and increasing the engine speed to the predetermined engine speed.